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ASSESSING SCHEMA KNOWLEDGE

Sandra P. Marshall

May 1988

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# Center for Research in Mathematics and Science Education

**College of Sciences**
**San Diego State University**
**San Diego, CA 92182-0413**

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Sandra P. Marshall
Department of Psychology
Center for Research in Mathematics and Science Education
San Diego State University
San Diego, California 92182

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The purpose of this paper is to explore issues involved in the assessment of cognitive development. The paper is divided into four sections. In the first I examine the need for new theories of testing and for procedures that go beyond those currently in use. In the second section I propose an assessment model based upon schema knowledge. In the third I offer data from a computer-based instructional system designed to promote schema development. Finally, in the last section I summarize my findings and outline some important issues for future research.

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# ASSESSING SCHEMA KNOWLEDGE

Sandra P. Marshall
Department of Psychology
Center for Research in Mathematics and Science Education
San Diego State University
San Diego, CA 92182

The purpose of this paper is to explore some of the issues involved in assessing cognitive development. The paper is divided into four sections. In the first section I examine the need for theories of testing and for procedures that go beyond those currently in use. In the second section I propose an assessment model based upon schema knowledge, and in the third I offer data from an intelligent computer-assisted instruction (ICAI) system based on schemas. In the fourth section I summarize my findings and suggest additional questions that need to be addressed by further research.

## The Need for New Theories

A major focus in current educational and psychological research is on higher-order thinking skills. While these are, in a sense, just "buzz words", they suggest an interest in processes that go beyond retrieval of facts, algorithms, concepts, or rules. The emphasis is upon how an individual puts together the knowledge at his or her disposal and upon the product that emerges as a result of that synthesis. The measurement question that accompanies this new emphasis is: How can we assess this type of cognition and performance?

Elsewhere I have outlined two approaches that may be useful in the evaluation of schema knowledge, item response theory (IRT) and statistical graph theory, and I explored there some of these measurement issues (cf., Marshall, in press). I think that IRT and statistical graph theory are viable means for modeling schema assessment, but they are still far from being usable now. Both approaches contain important psychometric issues to be resolved. In the remainder of this paper, I adopt principally the graph theoretical perspective, but I do not attempt to deal here with some of the sampling and estimation problems I discuss in the earlier paper. My purpose in the present paper is to show how we can begin to assess schema knowledge even though a full testing model is not yet available.

## An Assessment Model for Schema Knowledge

In this section I address the issue of assessment of a particular kind of knowledge, generally called schema

knowledge. My interest in developing new theories of psychological testing stems from my research in knowledge and how individuals store, manipulate, and retrieve it from long-term memory. For several years I focused on the formation of schemas, and I have frequently considered the problem of how to evaluate for an individual whether these knowledge structures exist, whether they are partially constructed, whether elements of them are incorrect or simply absent, and whether they might be present but simply not used on a particular task. None of these is easily answered.

To make matters worse, the schema as a psychological construct has been poorly defined in my own area of cognitive psychology. Some researchers approach it from an architectural point of view -- that is, they are concerned primarily with the schema as a structural feature of long-term memory, usually specifying it as a set of nodes and arcs connecting those nodes. Other researchers emphasize the nature of the knowledge that is contained in the schema, that is, the particular content features.

If we are to assess schema knowledge adequately, we need to encompass both perspectives. Our assessment must take into account both how we believe knowledge to be linked (i.e., the structural properties) and what we believe to be stored in the schema (i.e., the content properties). We need to estimate not only the degree of connectivity and the size of the network
represented by the schema but also the different types of knowledge that have been accommodated by it.

As I said, these are not trivial questions. There is a great deal of psychological theory development to be done. We don't yet have a hard and fast conception of what a schema is. Nevertheless, I think we can begin to make progress by formulating a working definition, hypothesizing the necessary components, and testing those hypotheses. As we test the hypotheses, we of necessity become involved in building a new type of psychological testing. In the remainder of this paper I describe my attempts at modeling schema knowledge and evaluating the model with respect to students' understanding of arithmetic story problems.

The Nature of a Schema

A brief review of my previous work may be helpful. I have been working with a particular theory of schema knowledge and its formation for about two years. In this theory a schema consists of four distinct types of knowledge: feature recognition, constraint mapping, planning/goal-setting, and execution. These together

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comprise a network of schema knowledge, with the four components being the nodes and having links among them. Moreover, I assume that these four components are themselves structured as networks of nodes, with various linkages connecting these nodes.

The feature recognition component contains declarative knowledge about the schema, including a general description. All of the pertinent features that describe the content of the schema reside here. The constraint mapping component houses the set of rules that govern the instantiation of the schema. Certain conditions must be met if the schema to be used. The first component dealt with recognition of the basic features. This second one tests whether or not a sufficient set of features are present.

The third component of schema knowledge has to do with making plans for implementing the schema, making estimates about its outcome, and drawing appropriate inferences related to its use. The mechanisms for setting goals and subgoals reside here. Finally, the fourth component, execution, encompasses the rules and procedures by which the schema is formally implemented.

A successful call to a particular schema means that the individual recognizes a situation (feature recognition), determines if critical circumstances are present (constraint mapping), formulates appropriate plans for using the schema (planning/goal-setting), and carries out those plans (execution). For the schema to be a useful knowledge structure, these four components must be connected.

Each of the four types of knowledge forms a network. This network may or may not be connected to the other types of knowledge, depending upon the level of schema construction that has taken place. A fully developed schema would have many links among components as well as within them.

How are we to measure the development of a schema? Clearly one way is to examine its connectivity. One of the most important features of a schema is the degree to which its constituent pieces are connected to each other. In the language of cognitive psychology, this is an issue of activation. If an individual retrieves one particular piece of information, how many other pieces are also automatically retrieved and available for processing?

Consider the simple case represented in Figure 1. Here there are only two components, X and Y. Nodes A, B, and C are elements in one component; nodes E, F, and G are elements of the second. In Figure 1(a), these two

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components are unconnected, although each component itself is fully linked (i.e., each node is connected to every other node). Given a prompt to node A, an individual having this knowledge structure would be able to access all the information contained in component X but would be unable to access the nodes of Y. Similarly, a call to E would result in activation of Y while leaving X unreachable.

In Figure 1(b) the two components are linked through nodes A and E. Now a call to X would result in access to the nodes in both components. There are many ways that X and Y could be linked, ranging from a single connection as in Figure 1(b) to all possible connections, as shown in Figure 1(c). For simplicity, if all the elements in one component are linked together, all the elements in a second component are linked as well, and if there exists one or more paths between the components, the entire components are considered to be connected and can be represented as in Figure 1(d). The single arc between X and Y carries a weight indicating whether the link between the components is weak (as in Figure 1b) or strong (as in Figure 1c). Estimating the strength of this link will be an important task for those who wish to assess schema knowledge. This aspect of schema assessment takes into account the architectural structure of the schema.

A second way to measure schema knowledge is to focus on the types of knowledge that are linked together. That is, our target knowledge may have multiple links. Just knowing the number of links does not tell us all we want to know about the connectivity. The links may be connections to several different kinds of knowledge or they may be pointers instead to many instances of a single kind. Figure 2 contains two graphs illustrating different kinds of linkages. In part (a), node A has six arcs leading to six different nodes. Each of these is a terminal node, having no other connections. Typically, this configuration corresponds to a graph of a concept with various defining features linked to it (e.g., a bird has feathers, eats seeds, makes a chirping sound). The features are not themselves linked together. All of the nodes in Figure 2a represent the same type of knowledge. A different configuration is shown in Figure 2(b). Here, node A has four links, three within the component and one to a node in another component. This pattern suggests a better integration of knowledge.

## Schema Identification

Schema measurement requires specification of the schemas that are of importance in the domain. Let me give an example. In my own research I study how individuals

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learn to understand and solve arithmetic story problems. To
determine what the primary schemas are for this domain one
asks what one expects of a student who has mastery of the
domain. What would we like for the student to be able to
do? What should he or she demonstrate to exhibit
competence? For the case of arithmetic story problems it is
not enough that the students have mastery of operations.
What we expect of them is the ability to understand the
situation expressed as a story or word problem and the
skills to extract the necessary information from the
situation. These together with the means to carry out the
computations indicate mastery.

In addition to specifying the schemas, we must also
specify for each one the elements in the requisite four
components of feature recognition, constraint mapping,
planning/goal-setting, and execution. Thus, we construct
an ideal representation of the schema and specifies the
necessary links that should exist among elements (e.g.,
nodes) and between components (e.g., subgraphs). One can
think of the entire domain as a very large graph. Within
this large graph are subgraphs corresponding to the
individual schemas. Within these subgraphs are smaller
subgraphs corresponding to the components of the schemas.
Finally, within the subgraphs are even smaller subgraphs
consisting of the elements that form a single schema
component. Figure 3 is an example of a very simple domain
having three schemas.

As shown in Figure 3, several levels of connectivity
will exist. First, the schemas themselves ought to be
linked together to form a cohesive knowledge structure about
the domain. There will almost certainly be common elements
within two or more schemas and one expects that the larger
subgraphs would be linked together.

Second, within each schema the four components should
be connected. For a schema to be successfully instantiated,
all four parts of schema knowledge are necessary. The
components cannot function in isolation.

Finally, within any component one expects to have a
well-connected subgraph of nodes. The elements at this
level have the most similarity one to another and have the
most direct association. Many paths among nodes would be
expected rather than a single one. Similarly, one expects
to have a path from any node in the component to all other
nodes (but not necessarily a direct link from each node to
all others). The component level of the network is not
shown in Figure 3. Each of the nodes labeled D, C, P, and E
corresponds to a subgraph of individual elements linked
together to form the component.

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Given this model of a domain, we desire now to have a testing model that reflects it. The goal is a model that takes into account the specific nodes that are required of a schema and the ways in which those nodes are related to each other.

Several obvious points can be made. First, if we only want to test the individual elements within any component of schema knowledge, we can do so easily and can use the student's response to estimate the absence or presence of the element we test. We may decide that one test item per element is sufficient or we may wish to use multiple items. Similarly, we can evaluate whether the student has two elements of knowledge within the same component by constructing a test item that requires both. In many cases we may assume connectivity if the student can respond to the item with the appropriate elements. So, for example, if we are assessing the descriptive elements of a particular schema, we might ask a student to provide a general description of the relation for which the schema has been constructed. Each distinct feature given in the student's response can be treated as an element of the descriptive component and can be considered to be linked to all other features in the response.

When we move up a level of complexity to look at the components and their degree of connection, we have greater difficulty in constructing test items. The difficulty is that we must have test items that represent two different dimensions of schema knowledge. For example, suppose we desire to assess whether an individual has linked components of declarative and planning knowledge. Our test item must call for demonstration that the declarative component is already established, for evidence of planning knowledge relevant to the schema, and for the application of the second to the first. The item needs to be well constructed. In particular, if the student answers the item incorrectly, we want to be able to ascertain from the response whether the error arose in the declarative component, in the planning component, or in the link between the two.

The purpose of cognitive assessment as it is presented here is to estimate how fully developed and how completely related are the components of schema knowledge for an individual. Each test item contributes to our estimate of the pieces of knowledge and/or to their connectivity. In the assessment of schema knowledge, not all test items provide the same degree of information about the individual. Some items test many distinct parts of the schema model and hence provide multiple estimates. Some test only a single

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element or a single link. Consequently, the items may need to be differentially weighted.

In the following section I give examples of different assessment items and the nature of the diagnostic information we gather from these items. Profiles are developed for a small number of students to demonstrate how the information can be aggregated.

## Current Implementations

I have recently developed an ICAI system designed to teach students how to understand the relationships expressed in arithmetic story problems. This system was created around five specific schemas used in arithmetic. Each of the four knowledge components of these five schemas is explicitly addressed in the system, and we have a number of diagnostic tasks that are intended to evaluate whether or not students have encoded and linked together the necessary pieces of knowledge. Details about the five relations taught by the ICAI system may be found elsewhere (Marshall, Pribe, & Smith, 1987).

A necessary part of the system is the assessment of whether or not a student has acquired the requisite knowledge at a particular time. The most common method of evaluation of ability to solve arithmetic story problems is to present a set of problems and to count the number of problems for which the correct numerical solution was obtained. Such an approach tells us little about schema formation or development and offers almost nothing of diagnostic value about which components of the schema are weak or incomplete.

It is important to say here that we never ask students to perform this traditional task in our ICAI system. We focus the evaluation questions instead upon specific aspects of each schema. Below I briefly describe the types of instruction we give and the questions we ask. Details about the curriculum and the particular schemas are not elaborated in this paper. The following description is intended to provide a general framework within which to discuss the types of evaluative items we use in the ICAI system.

Feature Recognition. The feature recognition component of a schema contains elements about the general structure of a story problem appropriate to that schema. Our primary concern here is not the assessment of each element within the subgraph "feature recognition" but rather the assessment of the entire subgraph. Consequently, our tasks for students focus on their ability to identify and discriminate

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among the situations that correspond to the five basic schemas we employ.

As part of the feature recognition or declarative portion of schema knowledge we expect a student to encode a verbal label for the relation in the schema, to encode a general description of the relation, and to encode a simple pictograph we use to represent the relation. Our instruction focuses upon these aspects.

Two tasks form the foundation of our assessment. In one of them, students simply examine a story problem and classify it according to situational labels (Change, Group, Compare, Vary, and Restate). Incorrect responses by students elicit feedback from the ICAI system that points out key elements of feature recognition for the particular problem. An example of this task is given in Figure 4.

For the second task we introduce the students to diagrams or pictographs for each situation (see Figure 5). Our intention here is for the students to associate the features of the situation with the appropriate diagram. Again, students are presented with a single story problem and given the choice of diagram from the five.

Constraints. As in the feature recognition instruction, the constraint instruction has two aspects, verbal and diagrammatic. The verbal constraints are conditions that must exist for the schema to be appropriately implemented. An example of a verbal constraint is the role of time in a Change relation. The change takes place over time. If the story problem does not develop over two different periods of time, it cannot reflect the change relation.

The diagrammatic constraints have to do with the number of different parts required by a relation and the ways in which they fit together. Each of the diagrams or pictographs have from three to five slots which are to be filled with information from the story problem. If too many of the slots are unfilled or if there are more features of the problem than slots in the diagram, the diagram is an inappropriate match for the story problem.

Again, there are two basic tasks. In the first task, students compare a set of story problems and attempt to identify the situations. Unlike the tasks of feature recognition, this task presents several problems at once to the student. Usually the student is given five problems, one for each of the possible schema situations. To complete the task successfully, the student not only compares a single problem with the five situations, he or she also must

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compare the problems to each other. For example, students frequently believe that two of the five problems demonstrate the same situation. Since the task is to identify one problem for each situation, the students must engage in constraint mapping to determine which of the problems actually evidences the situation and which does not.

In the second task, students are asked to use the diagrams and to map relevant pieces of the story problem into the parts of a given diagram (see Figure 6). The students do not select the diagram. The story problem and diagram are given, and the student merely moves pieces of the story problem into the diagram.

Other tasks explicitly link recognition features with constraints. The ICAI system presents a series of story problems to the student. For each story problem the student must select the appropriate diagram and demonstrate how the story problem maps into it. These tasks require several responses of the student. First the student identifies the appropriate diagram as in Figure 5. If the response is incorrect, relevant feedback is provided to the student by the computer. Next the student is shown the larger version of the appropriate diagram and asked to map the story problem (as in Figure 6). These tasks require the students to determine whether one schema situation is more appropriate for a given story problem than another. Further, they force the student to test for himself or herself whether the constraints of the schema are met by the particular problem.

Planning/Goal-Setting Questions. One of our objectives in the ICAI system is to help the student understand the problem and to be able to make plans about solving it. We actually do not assess planning alone. Our tasks are designed to look at planning and goal-setting with respect to feature recognition and constraints.

Two levels of planning are possible. First, the student has to anticipate where the unknown of the problem fits into the general schema situation. For example, the change situation has three parts: the beginning, the amount of change, and the result. In a story problem, any one of these three parts may serve as the unknown in the problem. Choice of arithmetic operation depends upon which part of the situation is unknown. We focus on this issue by having the student first examine a story problem and its appropriate blank diagram and then place the word UNKNOWN in the appropriate part of the diagram. (Later tasks relate the operation to the location of the unknown.)

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Other tasks about planning are relevant for story problems with multiple steps. Students learn to recognize which situation governs the problem and which subproblems must be solved before the top-level situation can be addressed. We use several tasks here. One calls for the student to identify in a diagram which parts are given in the problem, which are partially known but immediately solvable, and which are the true unknowns. Figure 7 contains an example of this task.

We also have the students identify the primary question asked in the problem. We work with them to identify secondary questions and the situations associated with them.

Execution Questions. With this last group of questions we come close to asking the students to solve the problems. However, our interest is not in whether or not they have mastered arithmetic algorithms. We are concerned with their ability to formulate the appropriate arithmetic expressions to reflect the problem situation. For example, students have a tendency to associate a particular operation with a type of problem. Take a Change situation as described above. Most students confronted with this situation want to perform an addition. This is not necessarily the appropriate operation. If the problem contains information about the starting amount and the change, and the change is an increase, then addition indeed is warranted. If, however, the student is given the amount of change and the final amount, addition will not solve the problem.

Our tasks that assess execution skills ask students to identify arithmetic expressions and verbal expressions about arithmetic operations. Feedback on these tasks stresses the importance of identifying the situation correctly and then observing which part of the problem is unknown.

This portion of the ICAI system is the briefest. Our current emphasis is primarily upon the recognition features, the constraints, and the planning components. Consequently, our assessment of the execution component of schema knowledge is not as strong as the assessment of the other three components.

Summary of the ICAI Evaluation. I have described the questions used in the ICAI system and given examples to point out how they differ from traditional questions assessing ability to solve arithmetic story problems. A primary asset of these tasks is that they allow us to estimate which aspects of schema knowledge have been encoded in memory and which remain to be formed. Following this series of tasks, we expect to determine for each student how fully each of the five schema knowledge structures has been

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developed. We are currently analyzing the student responses to the items presented by the computer.

Four student profiles. Below I describe the data from four students and how we estimate their schema knowledge for one particular relation, the Change relation. The data were gathered over five hours of instruction. All instruction was given within a two-week period. The students were college freshmen. Preliminary testing of these students indicated poor problem-solving skills. On a test of 10 multi-step story problems, the four students (J, N, P, and S) answered correctly 7, 5, 5, and 7 problems respectively. Table 1 contains data from these four students as they worked with the ICAI system. All of the students responded to approximately the same number of story problems. Their relative performance is given in the table.

We would like to infer from student performance that individuals who are more successful in solving problems have greater understanding of the domain than students who are less successful. From the overall performance percentages we can only conclude that some students answered more items correctly. With this information alone we cannot tell whether or not their schema knowledge differs.

In the lower part of Table 1 are profiles of these four students, based upon an analysis of the tasks as described above. We do not have data to look at all possible components and connections. In particular, these students did not complete the execution portion of the ICAI system. Thus, this component is excluded from the analysis. Second, only Feature Recognition and Constraints are assessed as components. While we provided instruction about planning elements, our Planning tasks themselves explicitly link the planning activities either to feature recognition or constraints. Thus, the profiles have some of the components and some of the connections. Nonetheless, it is useful to compare the profiles of the students.

Students J and N primarily had difficulty in encoding feature recognition elements. Most of their errors are on these items. Since feature recognition occurs early in our instructional system, these two students apparently erred early, learned from their errors, and then continued with a high degree of accuracy. Neither of these students had a great deal of difficulty with the constraints or the planning connections.

Student P had moderate success with the components of feature recognition and constraints but was less successful in connecting the three types of knowledge. In particular,

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Student P was weak in linking the constraints and planning elements.

Finally, Student S was generally weaker than the other students in all areas. The feature recognition elements were not well developed, nor were the constraints. These components in turn were then difficult for the student to link through the planning activities.

What do the profiles tell us? First, we see differences that are not evident from percentage of correct score alone. Second, we can use the information from the various items to estimate what aspects of schema knowledge are not well formed. If we intended to use the ICAI system as a diagnostic instrument for these students, we would select different subsequent instruction for them. Student J is doing well and should progress to the next level of instruction. Student N is performing adequately and should perhaps be reevaluated soon. This student also could move on. The other students need particular and different types of remediation. Student P had difficulty with the visual parts of feature recognition and constraint components. This student may need special instruction about the diagrams. In contrast, Student S needs assistance in forming connections. The degree of connectivity displayed here is low and needs to be improved.

Finally, we can use the profiles to evaluate the instructional system. Which parts of the system are most effective? Which need to be modified? We are currently developing profiles for the remaining 16 students who have used the system. We anticipate that we will learn more about how schema knowledge is developed when we have analyzed the full set of data for the 20 students.

## Summary and Conclusions

In this paper I have presented some ideas about the types of knowledge we want to assess in individuals, and I have outlined a theoretical approach for making that assessment. Obviously, we still have a long way to go before we have a robust theory for testing schema knowledge. Nevertheless, I am encouraged by the results we have obtained thus far. We are able to parse our test items by the hypothesized components of schema knowledge, and we have achieved a profile of schema knowledge for the students who interact with our computer system.

Why do we want to measure schemas? The psychological theory of knowledge acquisition is closely tied to the primitive theory of schema assessment presented here. Under the assumption that the components of schema knowledge have

been appropriately identified, we can now equate understanding to schema formation. That is, understanding improves as an individual builds the components of schema knowledge and links these components together. The recent stresses on higher order thinking skills, understanding, "owning your own knowledge", and the construction of knowledge by the individual all are answered in some degree by schema theory.

The perspective developed in this paper is not a traditional testing approach. First, there are several attributes to be measured, because schema knowledge has many dimensions. Second, we are not concerned with a sample from a universe of items. The items must be well chosen but do not necessarily reflect the entire domain. It is likely that only a few items will be possible in a test of schema knowledge because responses to these items take more time than responses to conventional items. Probably assessment of individuals will involve different items. Once a particular linkage is demonstrated by the student response to a test item, we have no need to assess the link again. Failure to show the link, however, might lead to a set of probing questions to determine whether it is the link itself that is missing or the nodes that were to be connected.

Third, much of what we want to test involves intermediate processing. That is, we are less interested in a final answer than in the steps the individual took to obtain the answer. And finally, we want to make new kinds of inferences based upon the results of our assessment. We want to estimate how organized is the individual's knowledge of a domain and how well the individual can use the knowledge he or she has acquired.

Clearly the attempts to measure schema knowledge presented in this paper are just the first steps. For wider application we must develop new concepts of validity and reliability. The need for good estimates is as great for tests of schema knowledge as for a traditional test. One drawback to estimating validity is that we do not have alternative tests that measure schema acquisition. At this point we are validating the items by comparing them with interview responses given by the students at the end of each instructional session. In the interview we have the students describe what they have studied, have them define any concepts, have them demonstrate the ability to use the different parts of schema knowledge, and have them talk generally about complex story problems. We expect that students who have difficulty with the ICAI system will demonstrate similar difficulty in the interviews. Comparisons of student responses to the computer and responses in the interview are now underway.

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Many issues remain to be resolved in future research. Some have been pointed out above. Others include whether one should aggregate test item scores or develop a profile of knowledge. How would the aggregation be done? How would the contributions of each item be weighted? What advantages or disadvantages would aggregation have over the profile? Similarly, one needs to decide whether to develop a quantitative measure for each item or whether to accept qualitative scoring on some. Again, the advantages and disadvantages need to be studied. Further, we should look at the amount of time an individual takes to respond to items such as those described in this paper. Would reaction times be good measures of access or retrieval? Could the items be modified to use reaction-time measures? These and other related questions have yet to be studied.

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## Table 1

## Four Students' Responses to
## the ICAI presentation of CHANGE items

### GENERAL PERFORMANCE

| | STUDENT | | | |
| --- | --- | --- | --- | --- |
| | J | N | P | S |
| Number of items presented | 21 | 22 | 24 | 23 |
| Number of correct responses | 18 | 16 | 15 | 13 |
| Per cent correct | 86% | 73% | 63% | 57% |

### ANALYSIS OF SCHEMA KNOWLEDGE

| | STUDENT | | | |
| --- | --- | --- | --- | --- |
| | J | N | P | S |
| COMPONENTS: | | | | |
| Feature Recognition: | | | | |
| verbal | 66% | 50% | 50% | 66% |
| visual | 66% | 50% | 80% | 80% |
| Constraints: | | | | |
| verbal | 100% | 100% | 100% | 0% |
| visual | 100% | 75% | 72% | 64% |
| CONNECTIVITY: | | | | |
| Planning<-->Feature Recognition | 75% | 66% | 50% | 33% |
| Planning<-->Constraints | 100% | 100% | 33% | 50% |

# Figure 1

## Two Components and Possible Linkages
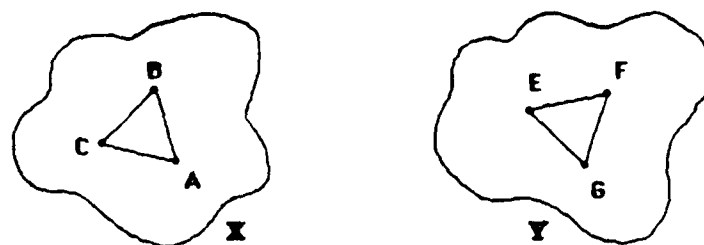


(a)
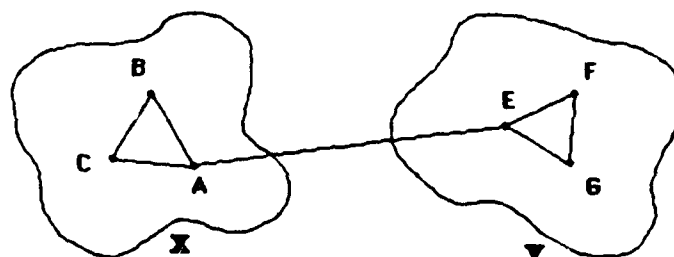
(b)
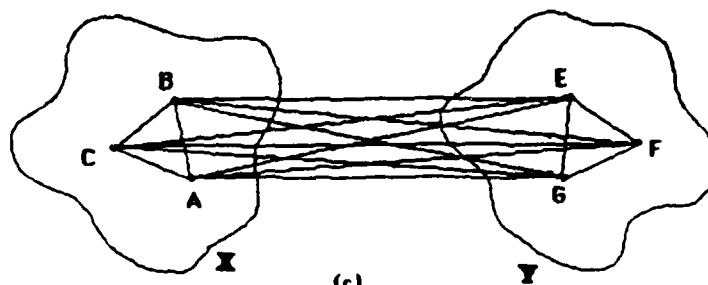
(c)
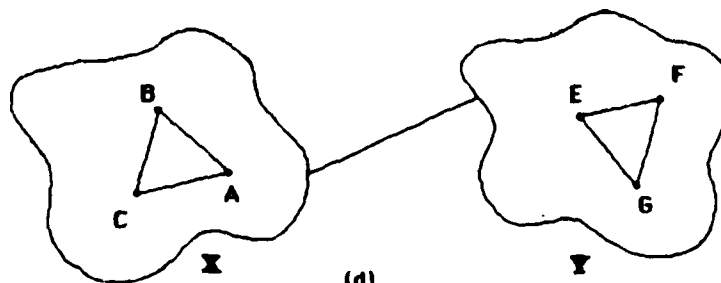
(d)

Figure 2

Two Patterns of Linkages
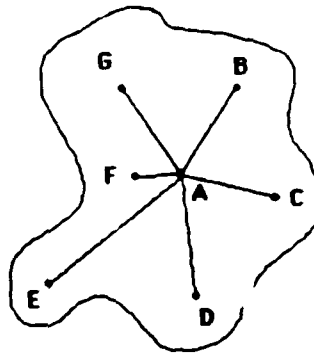


(a)
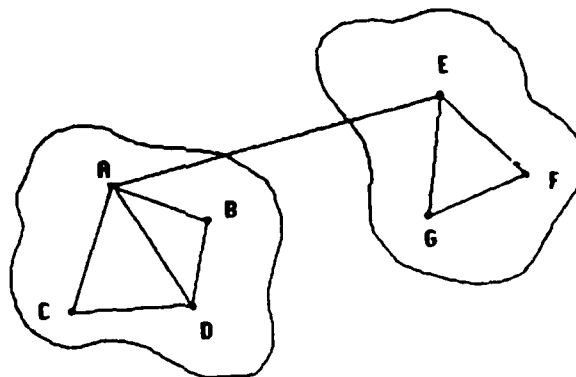
(b)

Figure 3

The General Mapping of A Domain
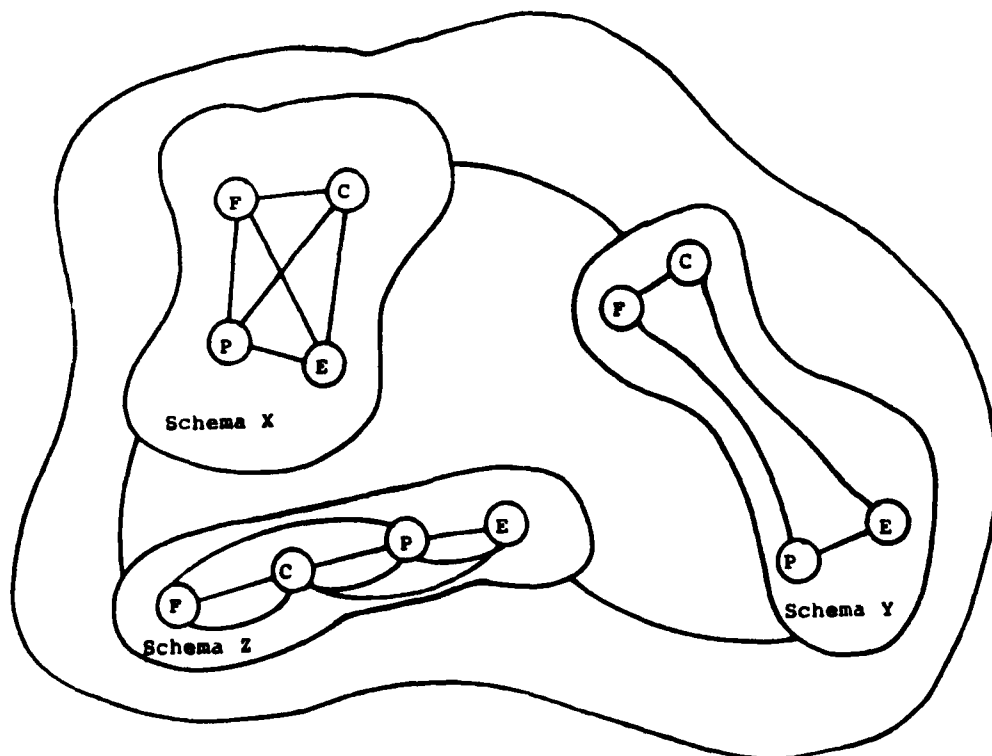
Figure 4

First Feature Recognition Task from the ICAI System

INSTRUCTIONS: Read the story below. Decide which of the
five situations best describes the story. When you have
made your choice, position the arrow on top of the one you
have selected and click the mouse button once.

The History Final Exam had 30 questions. There were
22 multiple choice items, 5 matching exercises, and
3 essay questions.

**Change**
**Group**
**Compare**
**Vary**
**Restate**

20

## Figure 5

## Second Feature Recognition Task from the ICAI System

INSTRUCTIONS: Choose the one diagram below that fits this story problem. Move the arrow into the diagram you have selected and click the mouse button.

Bill and Eddie both planted tomatoes this year. Bill harvested twice as many tomatoes as Eddie. Bill picked 64 tomatoes. How many tomatoes did Eddie have ?
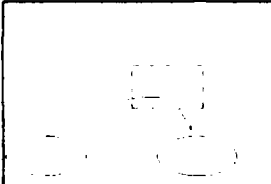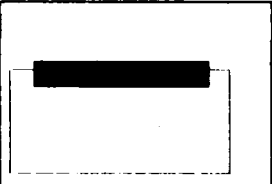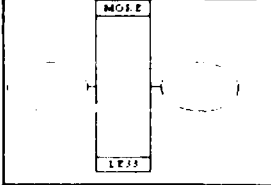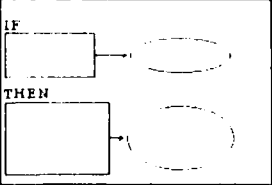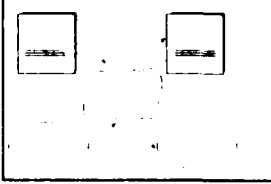
## Figure 6

## Constraints Task from the ICAI System

INSTRUCTIONS: Read the problem below. Identify the parts of the problem that belong in the diagram. Move the arrow over each part. Click and release the mouse button. Drag the dotted rectangle into the diagram, and click the mouse button again when you have positioned the rectangle correctly in the diagram. If you make a mistake, return to the problem and repeat the process. When you are satisfied with your answer, move the arrow into the OKAY box below and click the mouse button.

Joe's favorite tape had 15 songs on it. Last night he accidentally erased 10 songs. Now there are only 5 songs on the tape.

Figure 7

Planning Task from the ICAI System

INSTRUCTIONS: Read the problem below and study the diagram. For each part of the diagram, decide whether the necessary information is already GIVEN in the problem, whether you can find it by first getting a PARTIAL ANSWER, or whether you can find it as the FINAL ANSWER to the problem. Fill each part of the diagram with one of the three choices. Click in the OKAY box when you filled the diagram.

Jerry answered ten more problems correctly on the math test than Phil did. Jerry gave correct answers to 80 percent of the 50 items. How many items did Phil answer correctly?

GIVEN    PARTIAL ANSWER    FINAL ANSWER

Dr. Beth Adelson
Department of Computer Science
Tufts University
Medford, MA 02155

Air Force Human Resources Lab
AFHRL/MPD
Brooks, AFB, TX 78235

AFOSR, Life Sciences Directorate
Bolling Air Force Base
Washington, DC 20332

Dr. Robert Ahlers
Code N711
Human Factors Laboratory
Naval Training Systems Center
Orlando, FL 32813

Dr. John R. Anderson
Department of Psychology
Carnegie-Mellon University
Schenley Park
Pittsburgh, PA 15213

Dr. Nancy S. Anderson
Department of Psychology
University of Maryland
College Park, MD 20742

Technical Director, ARI
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Patricia Baggett
School of Education
610 E. University, Rm 1302D
University of Michigan
Ann Arbor, MI 48109-1259

Dr. Eva L. Baker
UCLA
Ctr for the Study of Evaluation
145 Moore Hall
University of California
Los Angeles, CA 90024

Dr. William M. Bart
University of Minnesota
Dept. of Educ. Psychology
330 Burton Hall
178 Pillsbury Dr., S.E.
Minneapolis, MN 55455

Dr. Lee Roy Beach
Dept. of Psychology (NI-25)
University of Washington
Seattle, WA 98195

Dr. Isaac Bejar
Mail Stop: 10-R
Educational Testing Service
Rosedale Road
Princeton, NJ 08541

Dr. John Black
Teachers College, Box 8
Columbia University
525 West 120th Street
New York, NY 10027

Dr. R. Darrell Bock
University of Chicago
NORC
6030 South Ellis
Chicago, IL 60637

Dr. Jeff Bonar
Learning R&D Center
University of Pittsburgh
Pittsburgh, PA 15260

Dr. J. C. Boudreaux
Ctr for Manufacturing Eng
National Bureau of Standards
Gaithersburg, MD 20899

Dr. Robert Breaux
Code 7B
Naval Training Systems Ctr
Orlando, FL 32813-7100

Dr. John Brown
XEROX Palo Alto Research Ctr
3333 Coyote Road
Palo Alto, CA 94304

Dr. John T. Bruer
James S. McDonnell Foundation
Suite 1610
1034 South Brentwood Blvd.
St. Louis, MO 63117

Dr. Joanne Capper, Director
Ctr for Research into Practice
1718 Connecticut Ave., N.W.
Washington, DC 20009

Dr. Susan Carey
Dept of Cognitive & Neural Science
MIT
Cambridge, MA 02139

Dr. Pat Carpenter
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

Dr. John B. Carroll
409 Elliott Rd., North
Chapel Hill, NC 27514

CDR Robert Carter
Office of Chief of Naval Operations
OP-933D4
Washington, DC 20350-2000

Dr. Davida Charney
English Department
Penn State University
University Park, PA 16802

Dr. Michelene Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

Dr. William Clancey
Institute for Research on Learning
3333 Coyote Hill Road
Palo Alto, CA 94304

Asst Chief of Staff for Research
Development, Test, and Evaluation
Naval Education and
Training Command (N-5)
NAS Pensacola, FL 32508

Dr. Paul Cobb
Purdue University
Education Building
W. Lafayette, IN 47907

Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
10 Moulton Street
Cambridge, MA 02238

Dr. Stanley Collyer, Code 222
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217-5000

Dr. Jere Confrey
Cornell University
Dept. of Education
Room 490 Roberts
Ithaca, NY 14853

Dr. William Crano
Department of Psychology
Texas A&M University
College Station, TX 77843

Dr. Cary Czichon
Intelligent Instructional System
Texas Instruments AI Lab
P.O. Box 660246
Dallas, TX 75266

Brian Dallman
Training Technology Branch
3400 TCHTW/TTGXC
Lowry AFB, CO 80230-5000

Dr. Robert B. Davis
Curriculum Laboratory (Education
University of Illinois
Urbana, IL 61801

Dr. Sharon Derry
Florida State University
Department of Psychology
Tallahassee, FL 32306

Dr. J. Stuart Donn
Faculty of Education
University of British Columbia
2125 Main Mall
Vancouver, BC CANADA V6T 1Z5

Defense Technical Information Ct
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC
(12 Copies)

Dr. Richard Duran
Graduate School of Education
University of California
Santa Barbara, CA 93106

Dr. Susan Embretson
University of Kansas
Psychology Department
426 Fraser
Lawrence, KS 66045